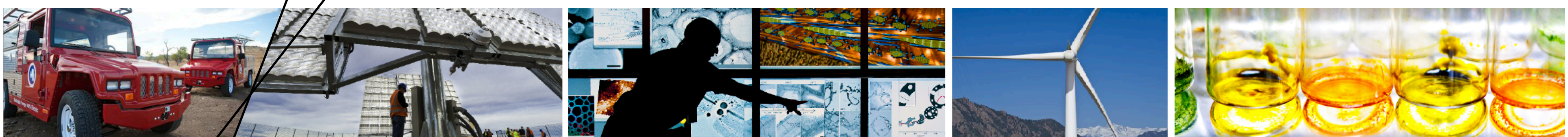
Estimating Renewable Energy Economic Potential in the United States: Methodology and Initial Results



Austin Brown, Philipp Beiter, Donna Heimiller, Carolyn Davidson, Paul Denholm, Jennifer Melius, Anthony Lopez, Dylan Hettinger, David Mulcahy, and Gian Porro

Webinar, 09/01/15

Presenters:

Steve Capanna
Director, Strategic Priorities & Impact Analysis
Office of Energy Efficiency & Renewable Energy
U.S. Department of Energy

Donna Heimiller
Sr. GIS Analyst
NREL

Gian Porro
Technology Manager
NREL

Philipp Beiter
Energy Markets and Policy Analyst
NREL

Topics

1. Summary of initial results
2. Background
3. General method summary
4. Resource data
5. Case descriptions
6. Initial estimates and observations
7. Summary
8. References

1. Summary of initial results

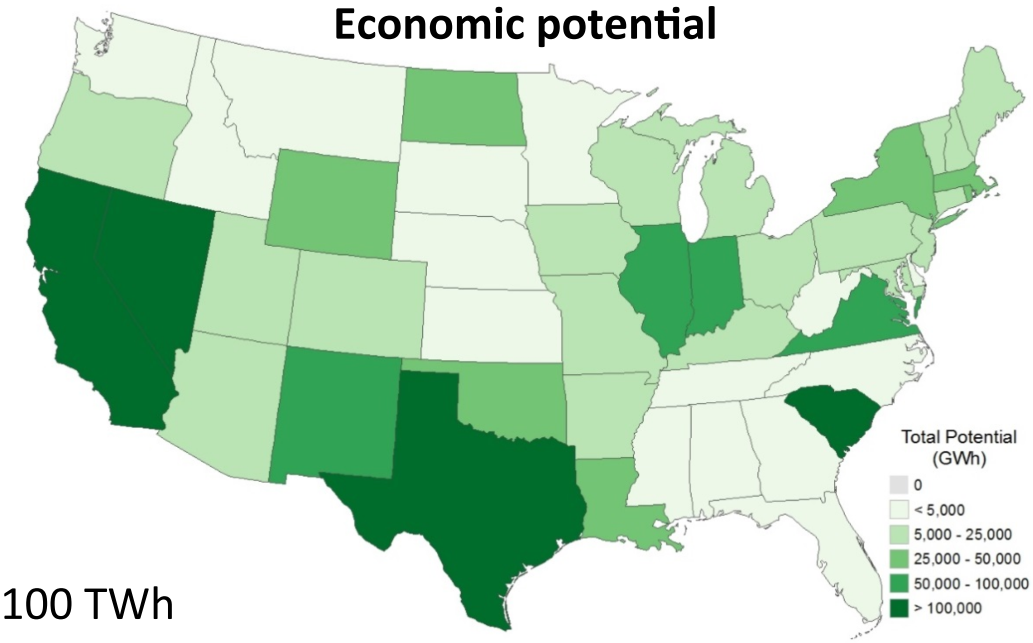
Economic potential:

- Ranges from one third to over ten times 2013 Total U.S. generation from all sources
- Appears in every state for at least one of the assessed technologies, depending on specific factors considered
- Increases considerably due to historic and projected technology cost reductions
- Is highly sensitive to specific assumptions

- In one primary case (2020 costs), economic potential is assessed to be*:
  - Wind: 548 – 869 TWh
  - UPV: 430 – 606 TWh
  - DPV: 287 TWh
  - Hydropower: 64 – 76 TWh
  - Geothermal: 131 – 153 TWh
  - Biopower: 0 TWh

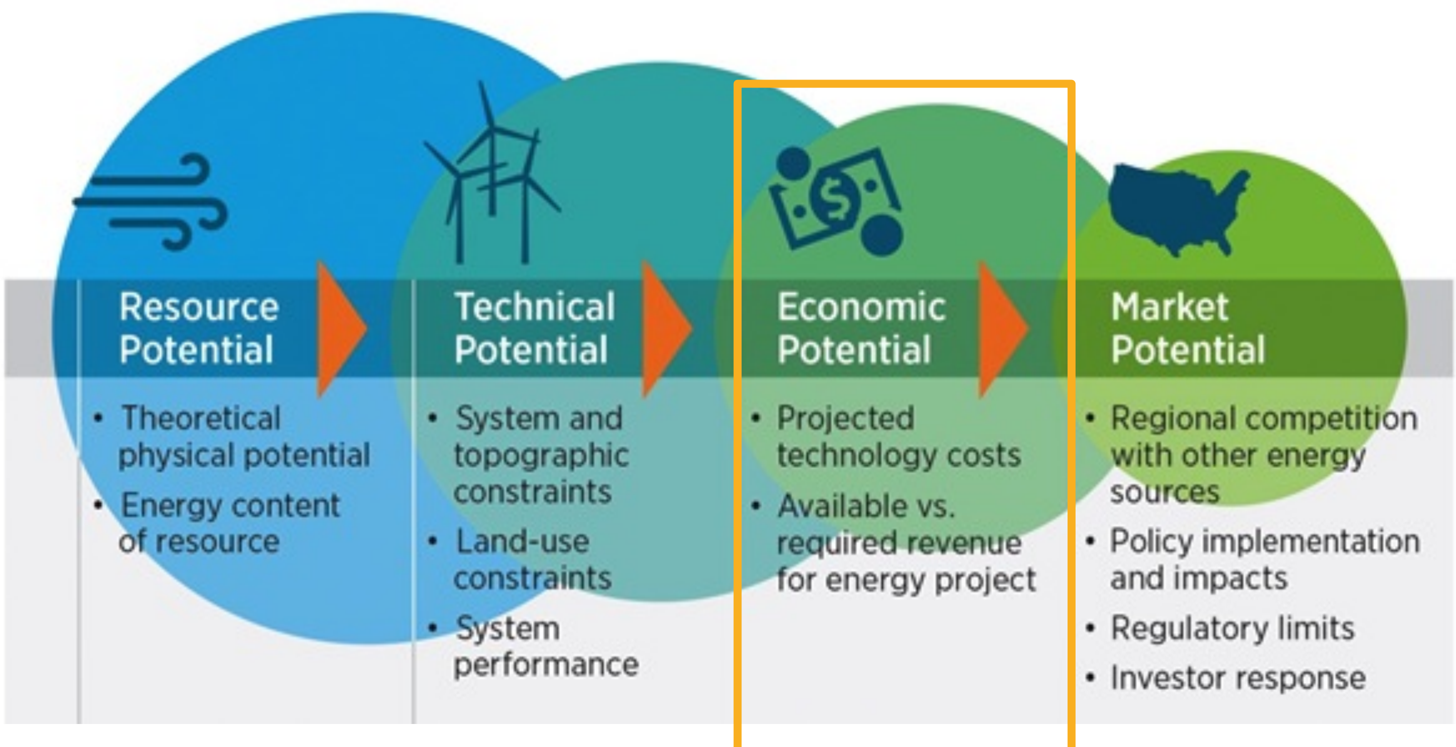
  - Total: 1,460 – 1991 TWh

Economic potential



* 2013 U.S. Total Electricity Generation: ~4100 TWh

Economic Potential



Economic potential is the subset of the available resource technical potential where the cost required to generate the electricity is below the revenue available

2. Background

Purpose

- To provide a high-level indicator of the **potential economic viability** of renewable electricity at a **detailed geospatial resolution** (more than 150,000 technology-specific sites)
- To capture the **significant variation** in local resource quality, costs, and revenue potential
- To apply the method to several renewable generation technologies **under a variety of assumptions**, including land-based wind, utility photovoltaics (UPV), distributed photovoltaics (DPV), hydropower, geothermal (hydrothermal resource only), and biopower (dedicated combustion plants only, not including co-firing)
- This analysis **does not** directly consider market dynamics, customer demand, exports from one site to another, or most policy drivers (e.g. CPP) that may incentivize renewable energy generation

- Results shown indicate generation **above and beyond current generation**

3. General method summary

Step 1: Technical potential

- Use best available renewable resource geospatial data to estimate the achievable annual generation of specific technologies at specific sites or within defined regions across the continental United States

Step 2: Cost of Supply (LCOE)

- Estimate the levelized cost of energy for each renewable generation technology at these same locations, incorporating regional plant construction costs , technology cost, performance and estimated intra-regional transmission costs

Step 3: Avoided Cost (LACE)

- Estimate a levelized avoided cost of electricity at these same locations by calculating the potential revenue available to a renewable generation project

Step 4: Economic Potential

- Calculate LACE – LCOE as the net value for a location
- A specific location is considered economically viable if its net value is positive; the technical potential associated with locations with positive net value is summed and deemed the economic potential

** The same general four-step approach is applied to DPV to estimate potential in the residential and commercial sectors, based on a method described in Denholm et al. (2009)*

3. General method summary

Core assumptions

- Construction Date: 2014
- Renewable Technology Cost: 2020 mid-projection
- Renewable Technology Incentives: Permanent 10% ITC for UPV, DPV; Accelerated deprecation (MACRS)
- Avoided Cost Method
    - Central Generation: A synthesis of locational marginal price and market marginal cost data from 2014 is applied as a proxy for marginal generation prices; accounts for projected electricity price increases over the life of a renewable generation plant (AEO 2014)
    - Distributed Generation: Local retail rates, together with full net metering where the customer is credited for any excess hourly generation at the applicable retail rate, are used as a basis for comparison to generation cost
- Project Life: 20 years

3. General method summary

Limitations

- The methodology does not attempt to project the amount of renewable generation that might **actually be deployed in the future:**
  - The framework described is static
  - It does not consider either **export or import** situations
  - The analysis relies on **available data sets** and **simplifying assumptions**

4. Resource data

Resource / Technology	Sites/Areas
Land-based wind	~100,000 sites
Utility-scale Solar PV (UPV)	~710,000 sites (aggregated to ~66,000 sites)
Hydropower	More than 280,000 individual sites aggregated to supply curves in 134 Power Control Areas
Geothermal	240 individual sites aggregated to supply curves in 134 Power Control Areas
Biopower	~3,000 county-level estimates aggregated to supply curves in 134 Power Control Areas

5. Case descriptions

Primary Case 1 – LACE Only:

- Direct LACE components plus the cost of intra-regional transmission for variable generation technologies (Wind and UPV).

Primary Case 2 - LACE including Value of Avoided External Costs

- Primary Case 1 plus the value of avoided external costs, in particular CO2 emissions.

Primary Case 3* - LACE including Value of Avoided External Costs and Declining Value of Variable Generation

- Primary Case 2 plus the impact of increasing amounts of variable generation

* Most results presented in this presentation will represent Primary Case 3

5. Case descriptions

Other factors considered in the framework

- Capacity value
- Technology tax incentives, including the Production Tax Credit (PTC) and Investment Tax Credit (ITC)
- The reduction of capacity and energy value of variable generation that may occur with increasing levels of generation
- The value of avoided CO_2 emissions, based on an estimate of the social cost of carbon (SCC)
- The value of avoided health costs

6. Initial estimates and observations

Presentation of results

- For illustrative purposes, intermediate results are presented for land-based wind
- Aggregated Economic Potential is presented for Primary Cases and sensitivities

Intermediate results	**I. Wind** 1. Technical potential 2. LCOE 3. LACE 4. Net value (LACE – LCOE)
Aggregated Economic Potential	**II. Sum of all technologies assessed** 1. Results for Primary Cases 2. Sensitivity results

6. Initial estimates and observations

Technical potential for land-based wind

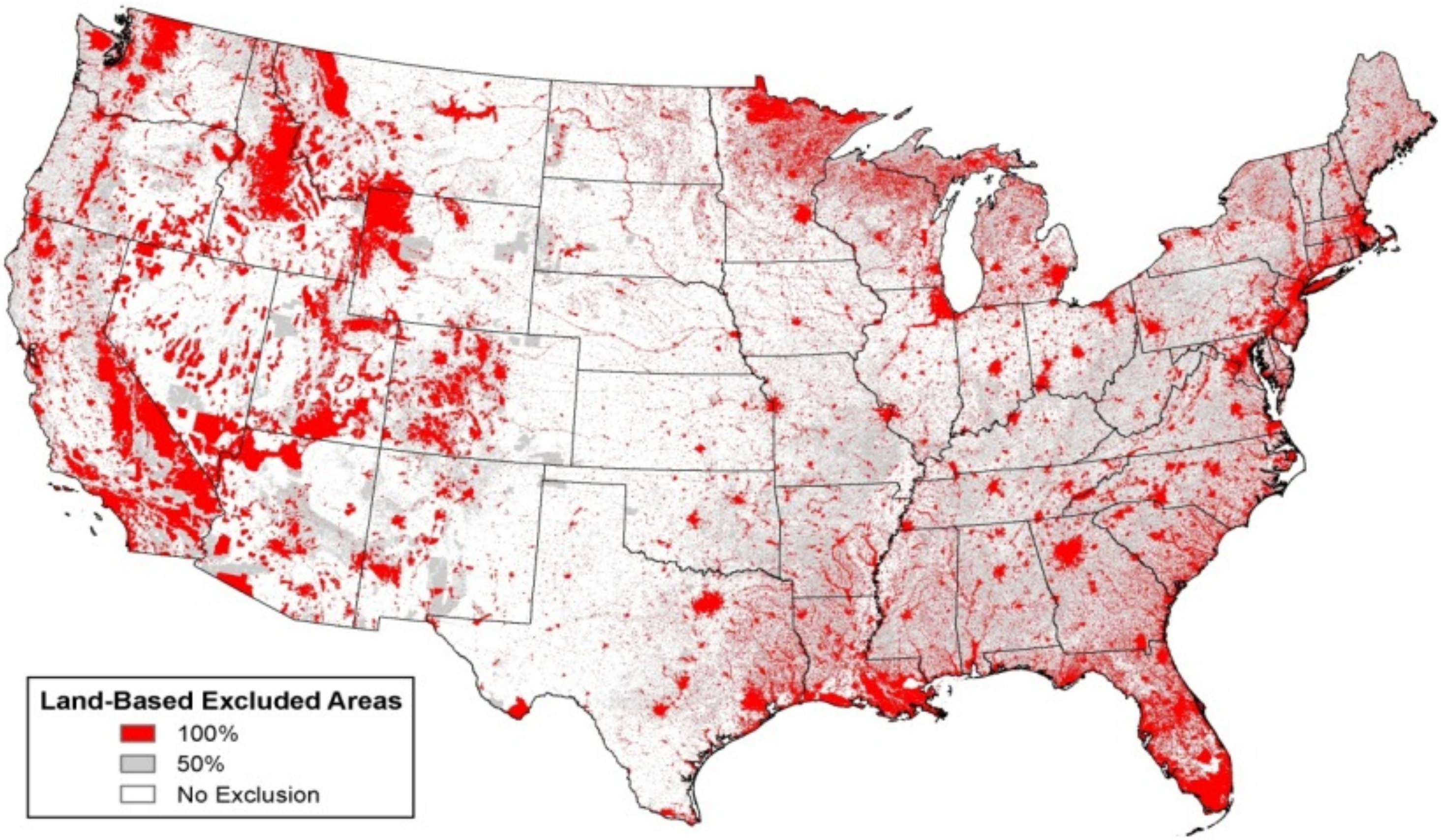
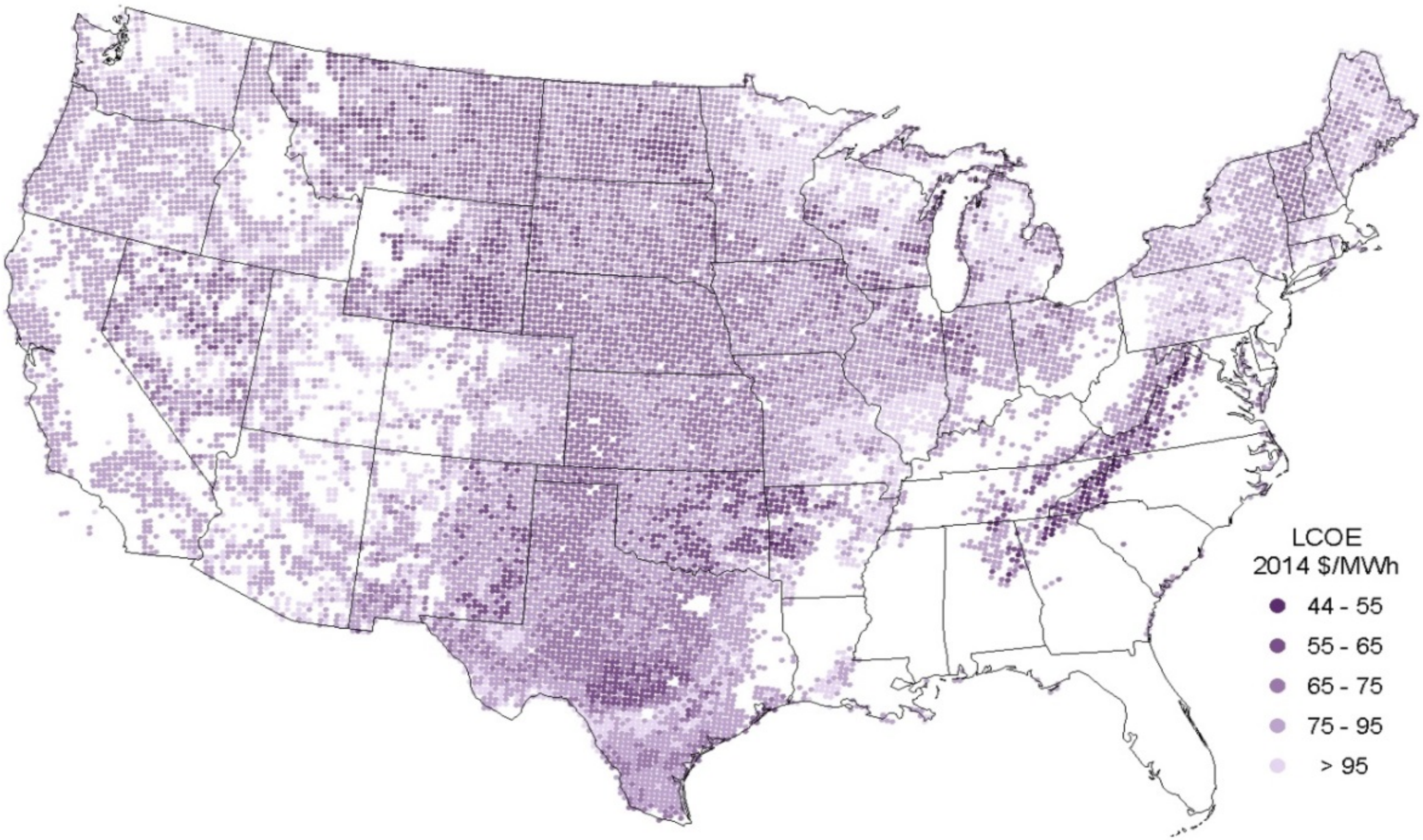


Figure 4. Land-based exclusion areas for land-based wind potential

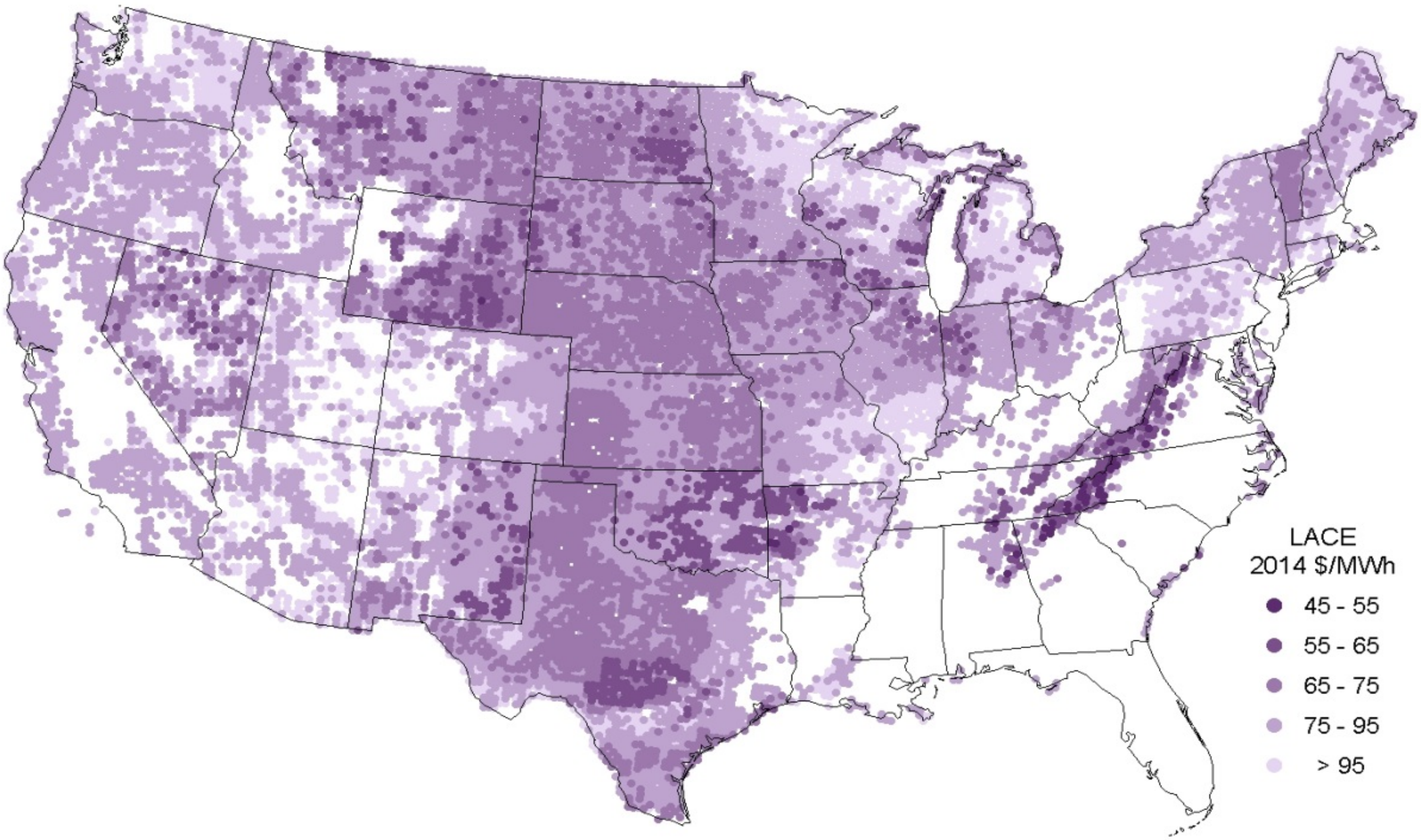
6. Initial estimates and observations

LCOE map for land-based wind (Primary Case 3)



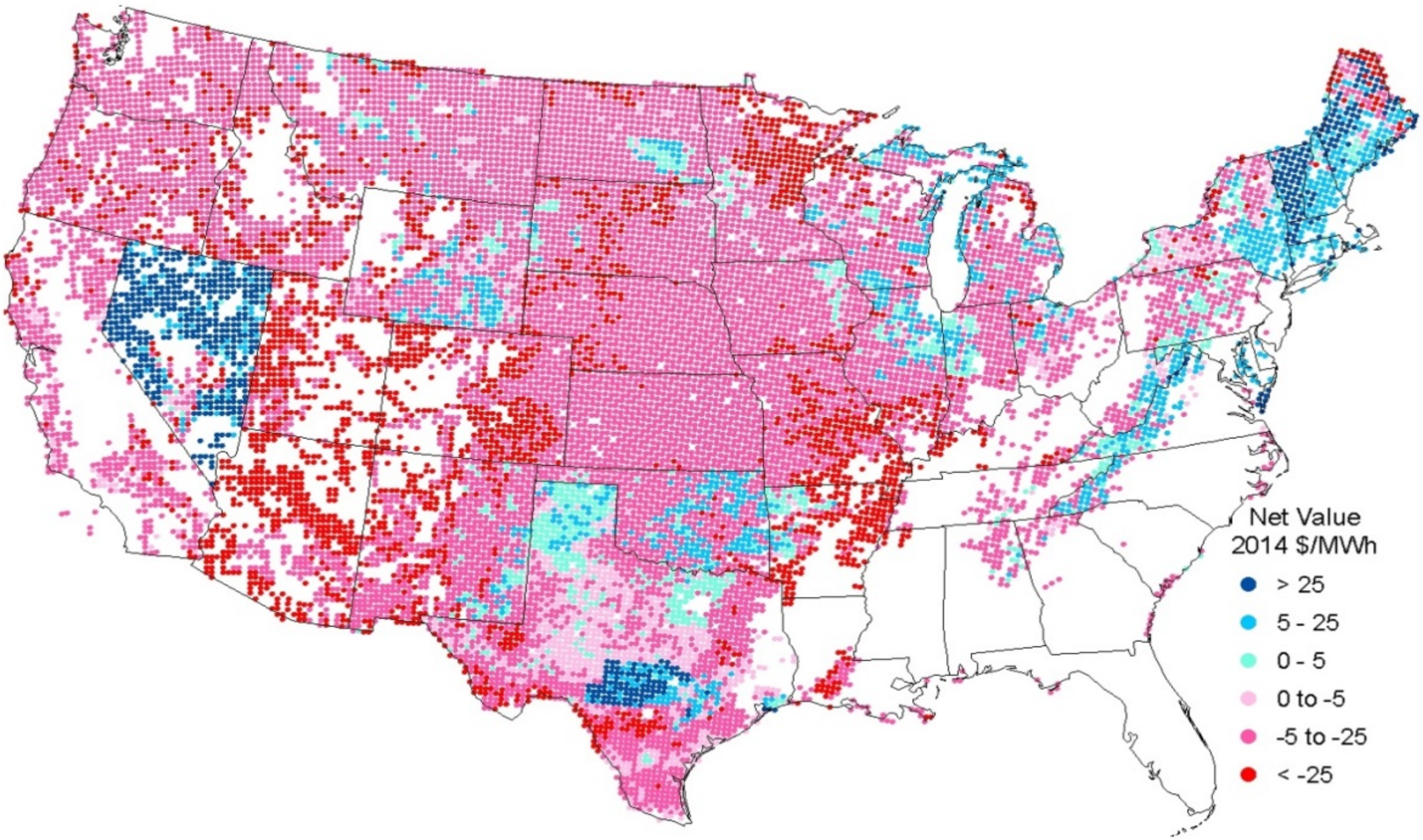
6. Initial estimates and observations

LACE map for land-based wind (Primary Case 2 and 3 with full capacity value)



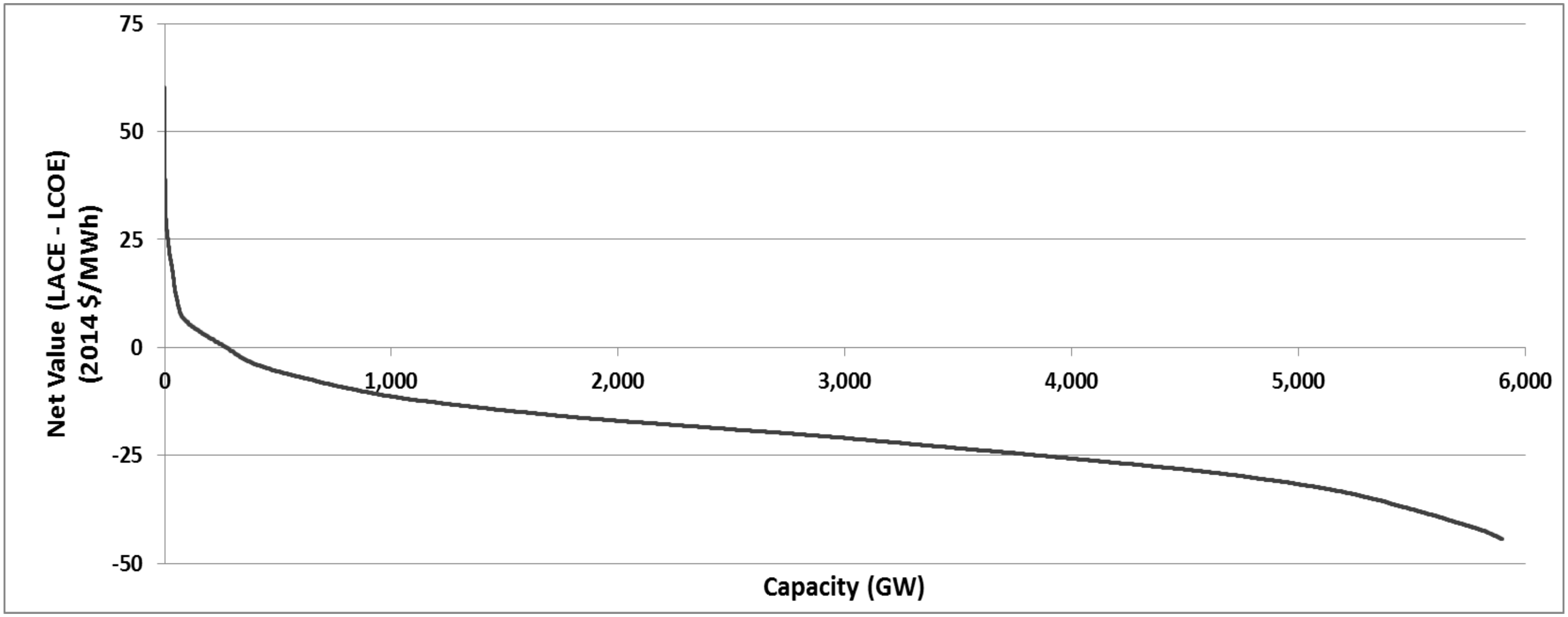
6. Initial estimates and observations

Net value map for land-based wind (Primary Case 3 with full capacity value)



6. Initial estimates and observations

Aggregated U.S. net value supply curve for land-based wind (Primary Case 3 with full capacity value)



Note: Capacity shown is incremental to 2013 level

6. Initial estimates and observations

Aggregated Estimated U.S. Economic Potential for Primary Cases

Primary Case	Specific Cases	Economic Potential - Annual Generation (TWh) Wind	UPV	DPV[5]	Hydro-power	Geo-thermal	Bio-power	Sum of Assessed
Reference Data	2013 Generation[1]	168	11	10	269	17	60	534
	Technical Potential[2]	22,195	297,475	1,560	278	234	445	322,187
Primary Case 1 - LACE Only[3]	Primary Case with Full Capacity Value	319	6,468	194	50	109	0	7,140
	Primary Case with No Capacity Value	135	2,789	194	38	29	0	3,184
Primary Case 2 - LACE including Value of Avoided External Costs[3]	Primary Case with Full Capacity Value	7,870	33,523	287	76	153	0	41,909
	Primary Case with No Capacity Value	4,590	7,713	287	64	131	0	12,785
Primary Case 3 - LACE including Value of Avoided External Costs and Declining Value of Variable Generation[4]	Primary Case with Full Capacity Value*	869	606	287	76	153	0	1,991
	Primary Case with No Capacity Value*	548	430	287	64	131	0	1,460

Notes

1 As reported in 2013 Renewable Energy Data Book (2014); including Alaska and Hawaii. Total generaton from all sources in 2013 was ~ 4100 Twh.

2 As updated in this report; excluding Alaska and Hawaii. Estimates may differ from prior assessments including Lopez et al. (2012) due to differences in the classification of resources (e.g., in some cases hydropower upgrades are not considered as new technical potential), advancements in technology (e.g., the availability of higher productivity wind turbines), or other factors.

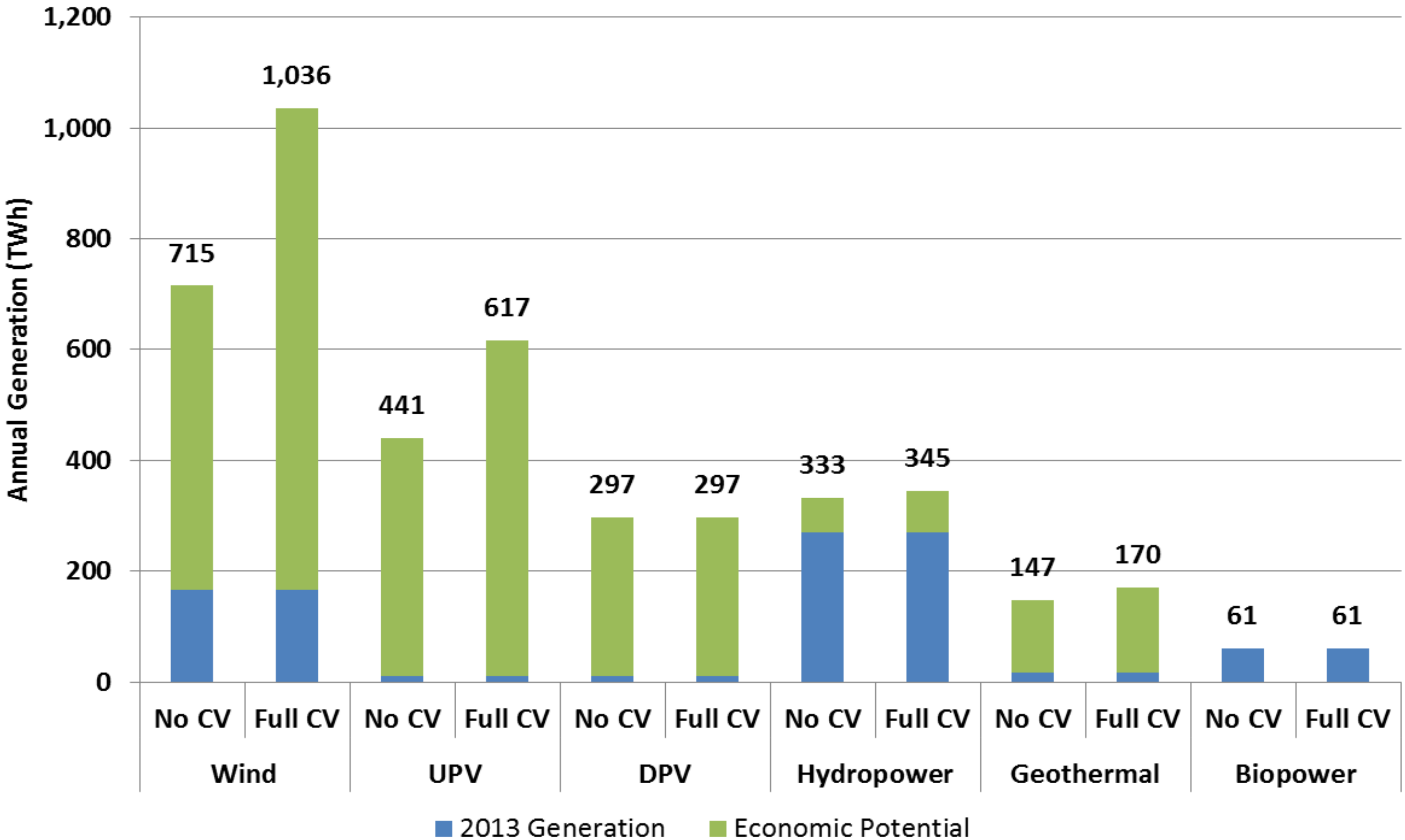
3 Does not include Alaska and Hawaii; in addition to existing generation.

4 Does not include Alaska and Hawaii; in addition to existing generation. Declining value applied to Wind and UPV only. An asterisk symbol (*) to the right of a case name indicates that wind generation potential exceeds 40% of 2013 total generation in some regions and may be overstated as the declining value method applied does not reduce the value of wind further as its potential share of generation exceeds 40%.

5 Not all cases run for DPV, hydropower, geothermal, and biopower; gray-shaded cells indicate that another case is used as a substitute.

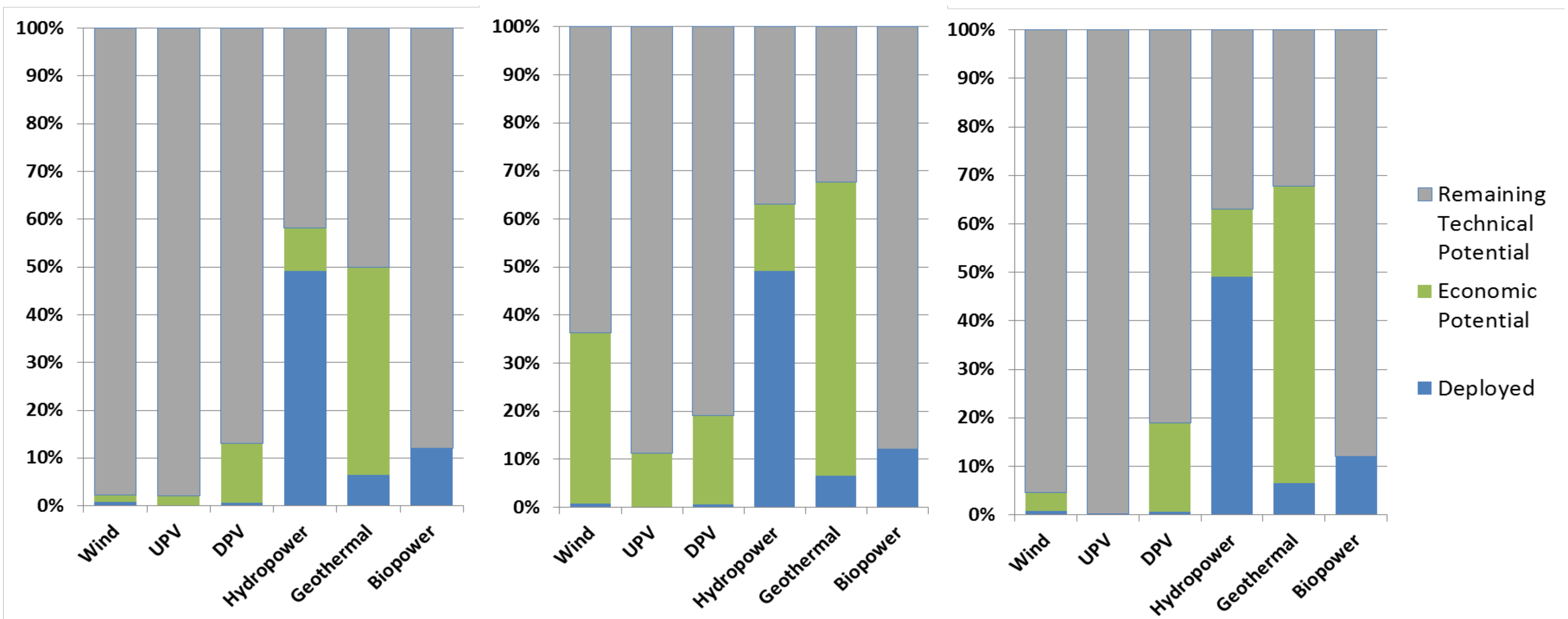
6. Initial estimates and observations

Aggregated Estimated U.S. Economic Potential (Primary Case 3)



6. Initial estimates and observations

Comparison of deployed, economic, and remaining technical potential



Primary case 1
(full capacity value)

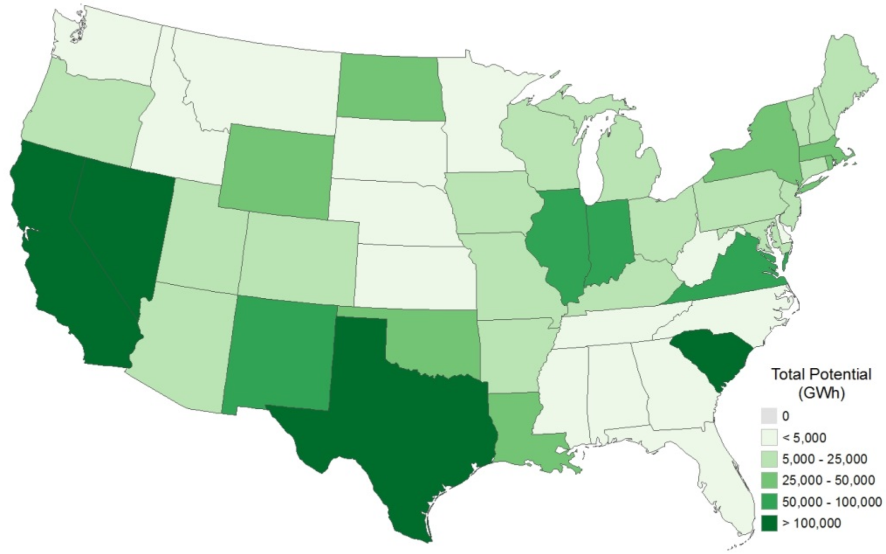
Primary case 2
(full capacity value)

Primary case 3
(full capacity value)

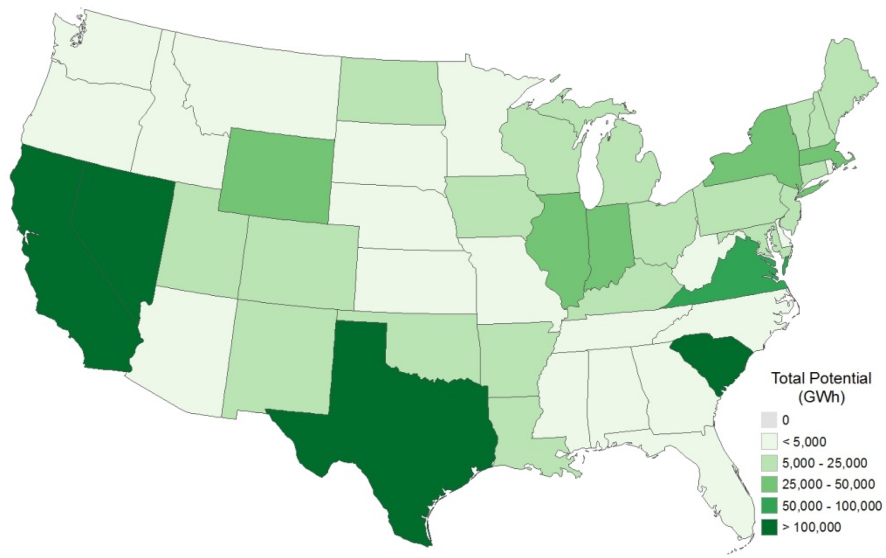
6. Initial estimates and observations

Aggregated Estimated U.S. Economic Potential for Primary Case 3

- **With full capacity value**

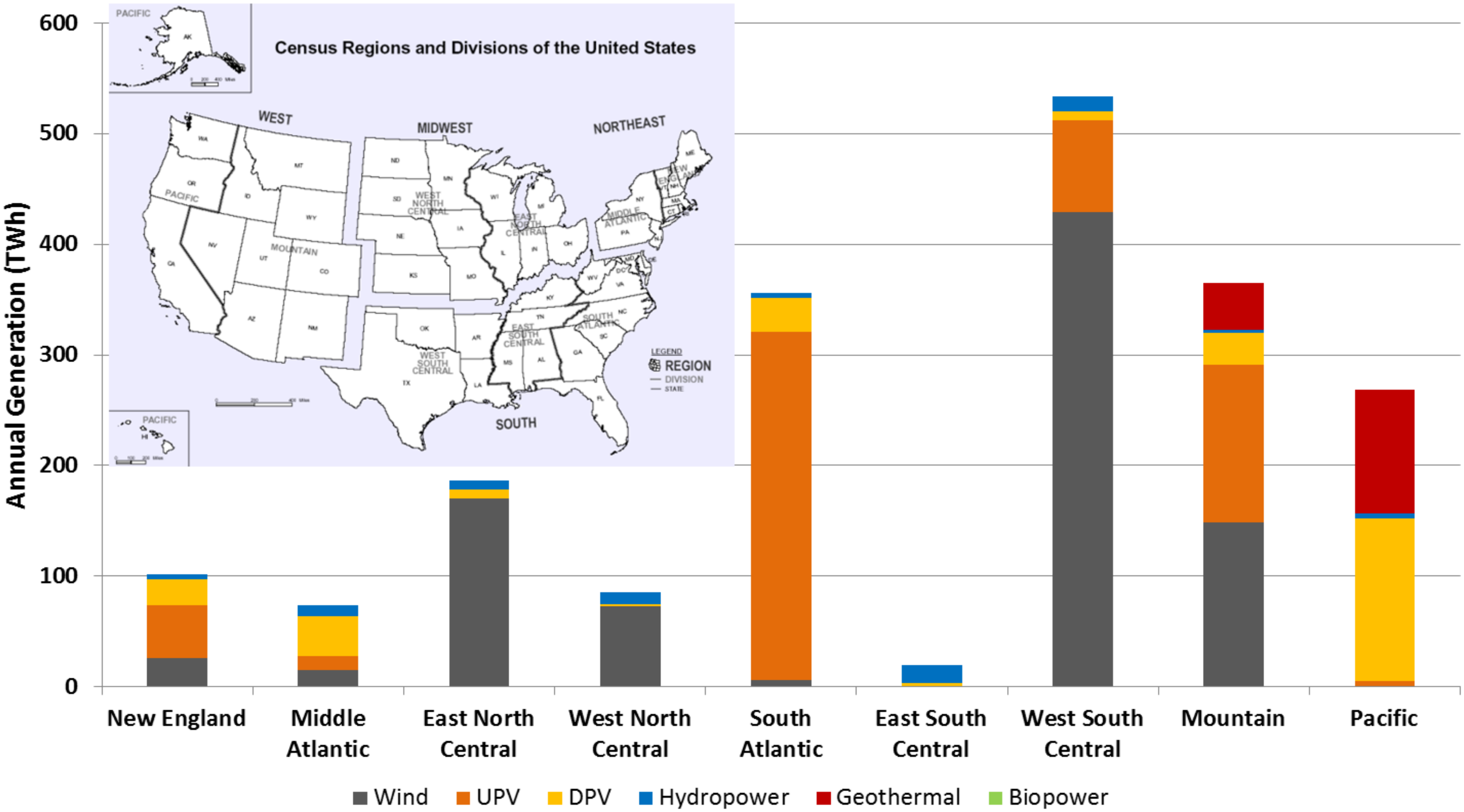


- **With no capacity value**



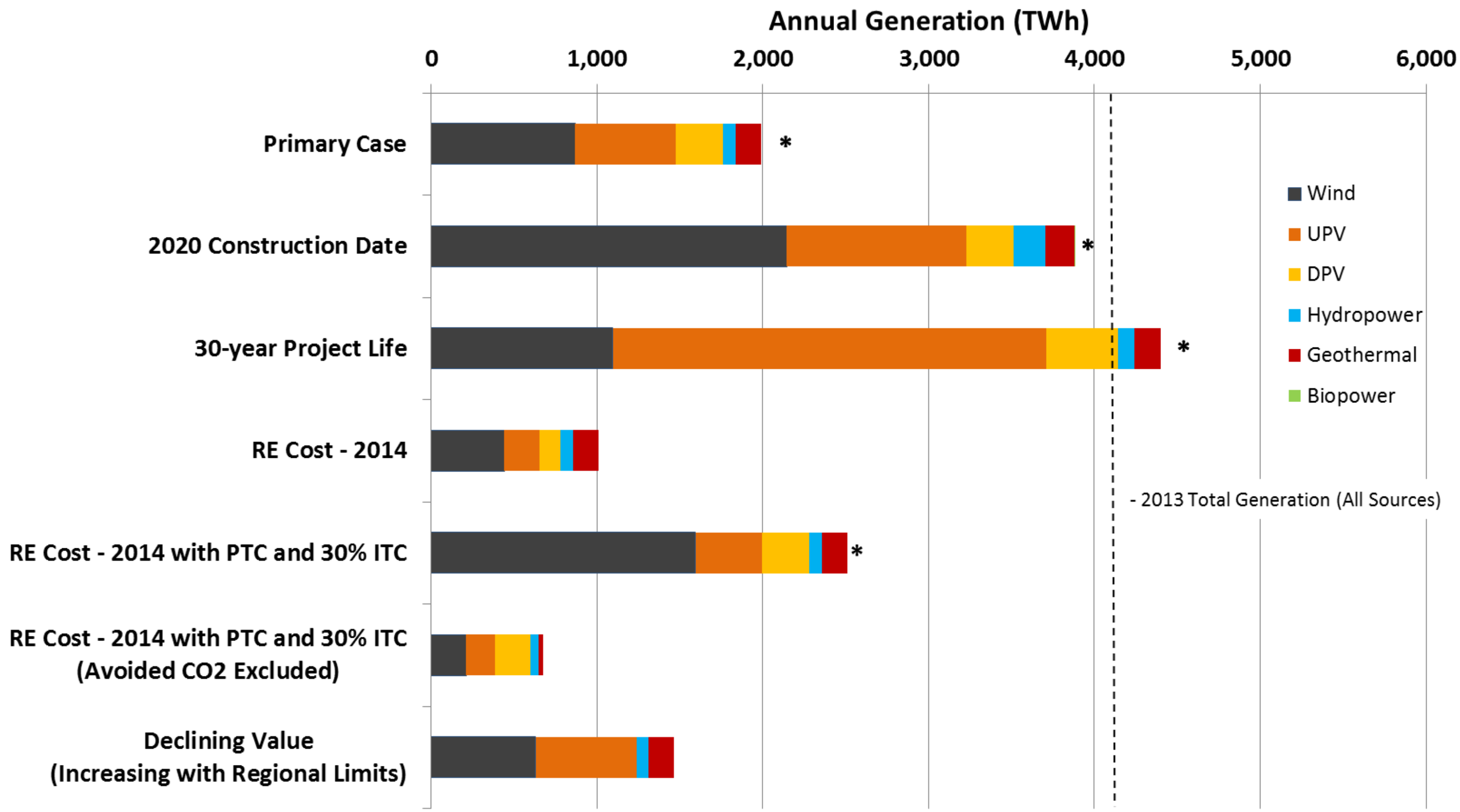
6. Initial estimates and observations

Aggregated Estimated U.S. Economic Potential for Primary Cases (Primary Case 3 w/ full capacity value)



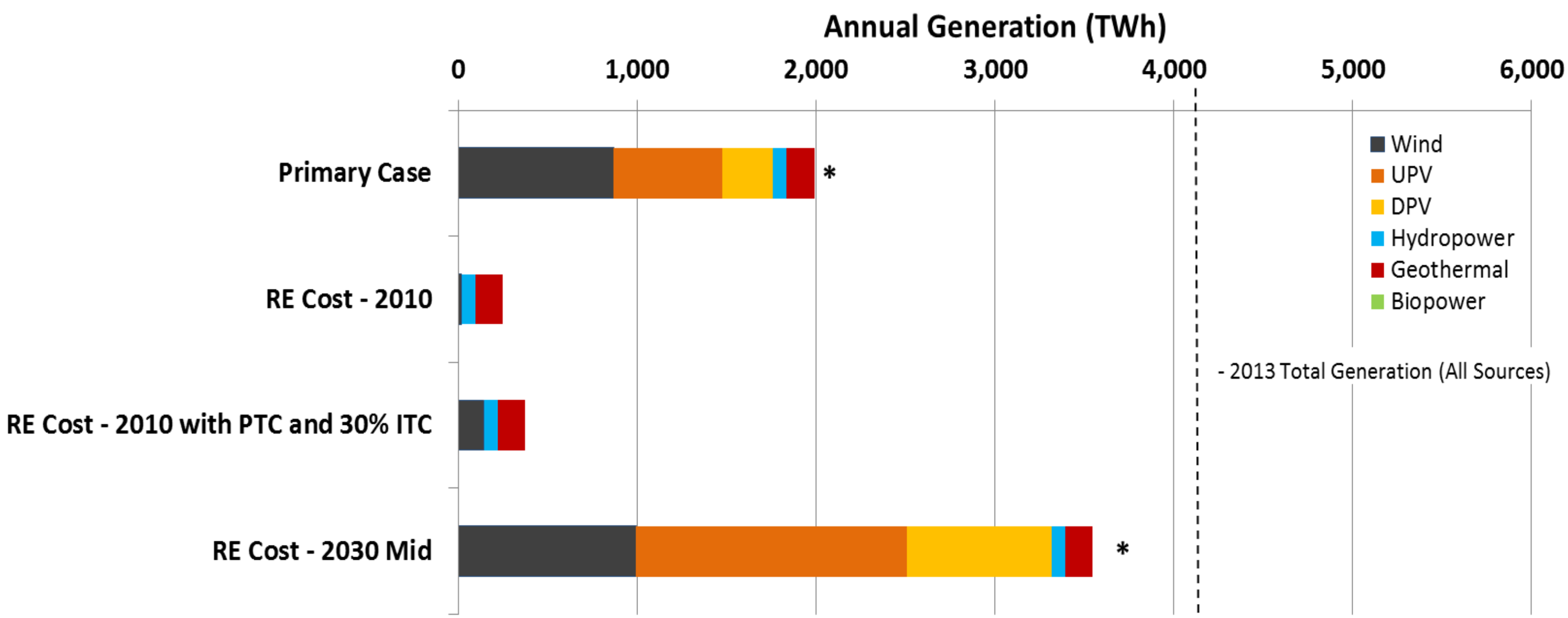
6. Initial estimates and observations

Sum of estimated U.S. economic potential – Framework sensitivities



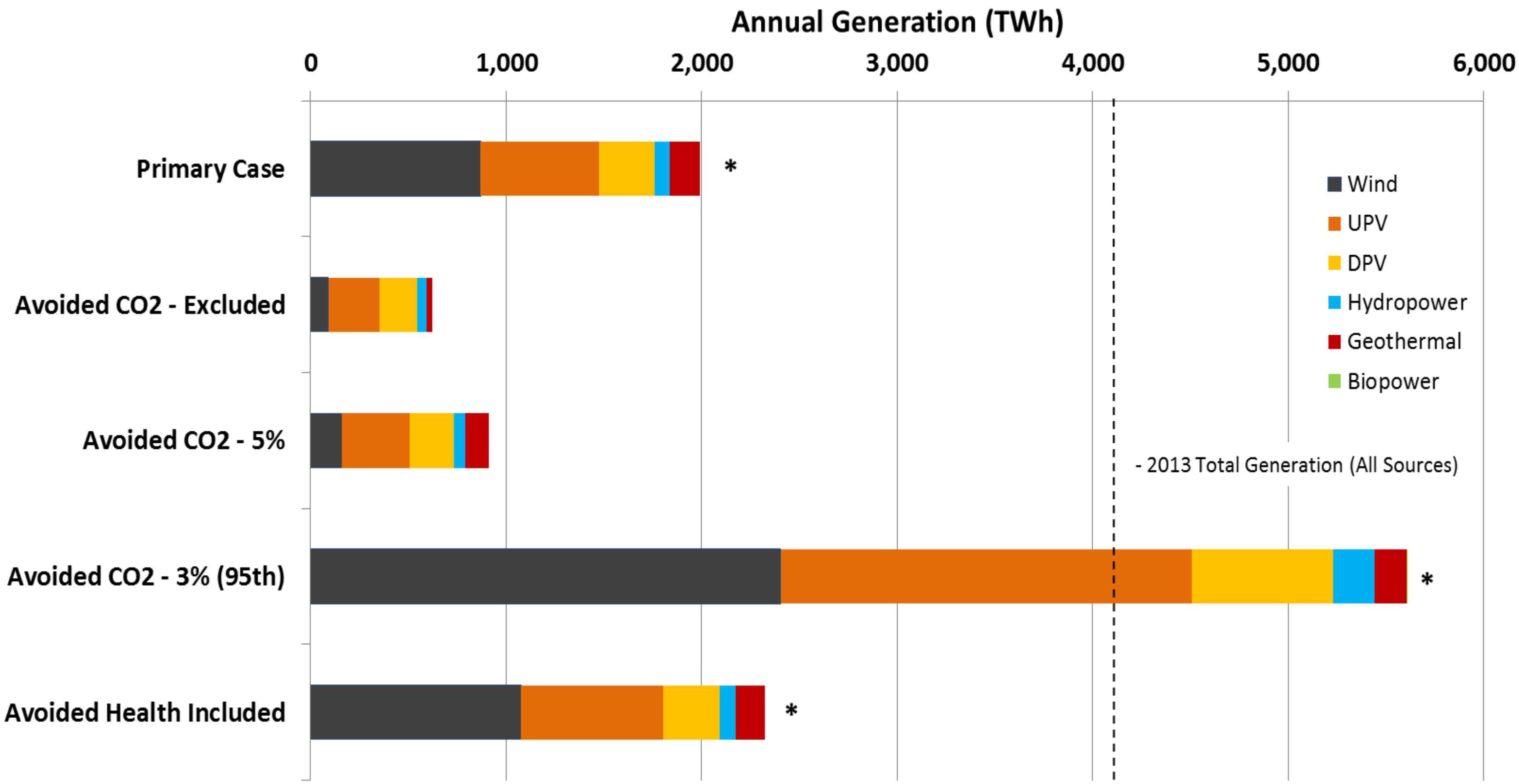
6. Initial estimates and observations

Sum of estimated U.S. economic potential – Renewable Technology Cost Sensitivities



6. Initial estimates and observations

Sum of estimated U.S. economic potential – Avoided External Cost Sensitivities



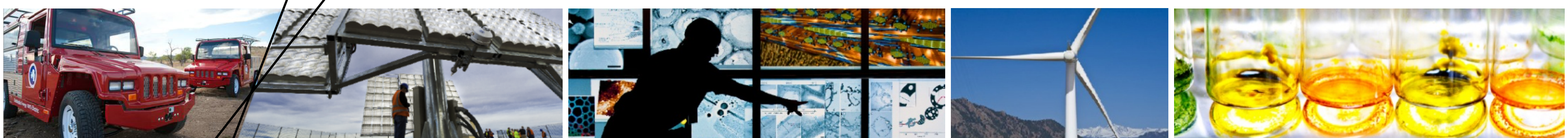
7. Summary

Initial results suggest:

- Economic potential metric can serve as a useful screening indicator for understanding the economic viability of renewable generation technologies at specific locations
- The specific formulation of the economic potential metric is extremely important. Estimates ranges from one third to over ten times 2013 Total U.S. generation from all sources
- Economic potential appears in every state for at least one of the assessed technologies, depending on specific factors considered
- Renewable energy technology cost declines between 2010 and 2014 have resulted in more than a tripling of economic potential
- Economic potential is highly sensitive to specific assumptions (e.g., consideration of Social Cost of Carbon, consideration of the declining value of variable generation with increased penetration, capacity value, technology cost, and construction year)

Potential further work:

- The spreadsheet-based model used to conduct this analysis is expected to be updated and refined to reflect new data and analysis as they become available
- Several improvement opportunities for the methodology, underlying data, and scenario analysis have been identified



8. References

Denholm, P.; Margolis, R.; Ong, S.; Roberts, B. (2009). Break-Even Cost for Residential Photovoltaics in the United States: Key Drivers and Sensitivities. NREL/TP-6A20-46909. Golden, CO: NREL